Appendix E
Case Study for Interior Flood Damage Reduction Measures, Valley Park, Missouri

E-1. Background

Valley Park is an incorporated community of about 4,300, situated in southwestern St. Louis County, Missouri. A portion of the city lies in the Meramec River floodplain, and is subject to flooding from events rarer than about a 10-percent annual chance of flooding. Valley Park is located about 22 miles upstream from the mouth of the Meramec River, which empties into the Mississippi River just downstream from St. Louis. The drainage area of the river at Valley Park is about 3,800 sq miles. Periodic flooding has been a problem, with significant flooding occurring in 1915, 1945, and 1957, and lesser amounts in other years. In December 1982, the flood of record occurred. Estimated as a 1-percent chance flood at that time, it flooded many low-lying areas of the community with 8 to 10 ft of water. In May 1983, another significant event (about a 4-percent chance flood) resulted in widespread flooding. In the mid-1980's, the St. Louis District investigated various flood mitigation projects for Valley Park and other communities along the lower 50 miles of the Meramec. Only a levee for Valley Park showed the necessary economic justification and a sponsor willing to cost-share the project. The Design Memorandum for the levee and accompanying interior flood control project was completed in February 1993. Construction began in the autumn of 1993.

E-2. General

The proposed levee project will protect about 461 acres of the city of Valley Park. It will protect against the 1-percent chance event from the Meramec River, and from coincident flooding from two tributaries: Fishpot Creek and Grand Glaize Creek. Almost no hillside area is included within the levee alignment. The protected interior area will be drained by six gravity outlets, with five ponding areas providing storage during blocked gravity outlet conditions. Open channels and drainage structures were also sized to convey the storm waters to the ponding areas. Although the interior analysis was fairly routine, it was the first application of the HEC-IFH computer program to analyze and design an interior system. The original beta test version of HEC-IFH was first used, with the updated versions incorporated as they became available.

E-3. Strategy

a. Interior flood control analysis is an essential part of the complete levee design, with a "minimum facility" being the first step. Because of several borrow areas and some natural storage located inside the levee alignment, it was believed that a minimum facility would mainly consist of gravity outlets and existing ponding. The duration of flooding for the Meramec River is short, with 4 to 6 days duration above flood stage for both actual and hypothetical events. Because of the short duration of blocked drainage, it was believed that interior facilities beyond the minimum would not be needed.

b. The approximate quantities of material to be removed from the potential borrow sites, as well as the amount of undeveloped areas usable for ponding, were known early in the interior analysis. The volume of the 1-percent chance flood, 4-day-duration storm was estimated, with the resulting runoff volume (about 200 acre-ft) filling the ponding storage. Consequently, it was decided to initially size the interior system for this storage, using a 1-percent chance event as the design standard. No economic incremental analysis was judged necessary for the interior analysis, because the borrow pit storage would be available for any design flood and changes in gravity outlet size(s) would be expected to show little reduction in peak ponding stages.

c. To fully test the design and the new program, both the HEA and CSA methods were used. A series of 4-day-duration hypothetical storms was used in the HEA to establish stage-frequency analysis for both open and closed gravity outlet conditions. The continuous period-of-record method (CSA) was then applied to establish the minimum facility and to compare against the stage-frequency relationship developed through the HEA.

E-4. Basic Data Requirements

Interior flood hydrology analyses are very data intensive, especially when both HEA and CSA techniques will be used. The following paragraphs identify the major data needs:

a. Subareas. Five interior drainage basins were identified, based on urban storm drainage systems and topographic contour mapping. These areas are identified as: the Fishpot, Highway 141, Glass Plant, Simpson Lake, and Grand Glaize interior areas. The Highway 141 subarea consisted of two subbasins, with a diversion to the Fishpot subarea during blocked outlet conditions. The other four subareas each consisted of a single subbasin. Separate HEC-IFH analysis would be performed for each of the five subareas, with each including gravity outlet and ponding storage. Table E-1 gives pertinent data for the interior areas and Figure E-1 shows a schematic diagram. Two-foot contour interval topographic mapping was available for the lower 50 miles of the Meramec from the earlier analysis.

Table E-1
Interior Unit Hydrograph Parameters

Interior Location	Designated Interior Basin*	Drainage Area (sq mi)	Runoff Coefficient (percent)	SCS T(LAG) (HR)
Fishpot	FPI	0.08	85	0.11
Highway 141	HYW & HYW1	0.05	90	0.17
Highway 141 with Outlet Closed	HYW1	0.02	95	0.06
Glass Plant	GPT	0.37	85	0.31
Simpson Lake	SIM	0.11	85	0.13
Grand Glaize	GG1	0.09	85	0.11

*From Figure E-1

b. Precipitation. Both hypothetical and continuous precipitation data would be necessary for the analysis.

(1) Hypothetical storm time series were developed from the appropriate National Weather Service publications with a 10-minute time interval used, due to the short concentration times of the interior basins. The 50- through 0.2-percent chance exceedance hypothetical storms were generated.

(2) Because of the short duration of flooding for both the tributary and the interior streams, time increments less than 24 hrs were needed for the CSA. Hourly precipitation records were available at the St. Louis, Missouri, rainfall station from 01 October 1948 to 30 September 1988. This precipitation data stream could be readily transferred to the Valley Park site for use with the CSA portion. Because of the short time of concentration of the interior unit hydrographs, it was initially felt that a 1-hr duration was too long to accurately define the interior hydrographs. The initial CSA analysis used a 10-min time-step and each 1 hr of rainfall data was subdivided into 10-min increments.

c. Subarea runoff parameters. SCS unit hydrographs and simple runoff coefficients were used to generate interior runoff hydrographs based on expected future conditions. Adopted values are shown in Table E-1.

d. Exterior river stage. Long record stage and discharge information was available for the Meramec at the Eureka gauge, located at River Mile 34.1, beginning in 1922. Daily stage data for the period October 1948 through September 1988 was assembled and transferred 12 to 14 miles downstream to simulate exterior river stages at each Valley Park outlet site. Transfer relationships between the Eureka gauge and each outlet site were developed through water surface profile analysis and are shown in Table E-2.

Table E-2
Eureka Gauge Transfer Curves

Eureka Gauge Elevation (NGVD)*	Fishpot Creek Elevation** (NGVD)	Glass Plant Elevation (NGVD)	Grand Glaize Creek Elevation*** (NGVD)
429.09	415.52	415.14	413.54
435.89	421.43	420.97	419.10
440.64	424.73	424.19	422.18
444.73	429.30	427.87	425.75
446.55	431.69	430.55	428.38
447.23	432.66	431.76	429.63
448.29	434.07	433.17	430.97
452.99	440.95	439.09	436.83
456.36	444.12	442.70	440.73

* National Geodetic Vertical Datum.
** Also used for Highway 141 subarea analysis.
*** Also for the Simpson Lake subarea analysis.

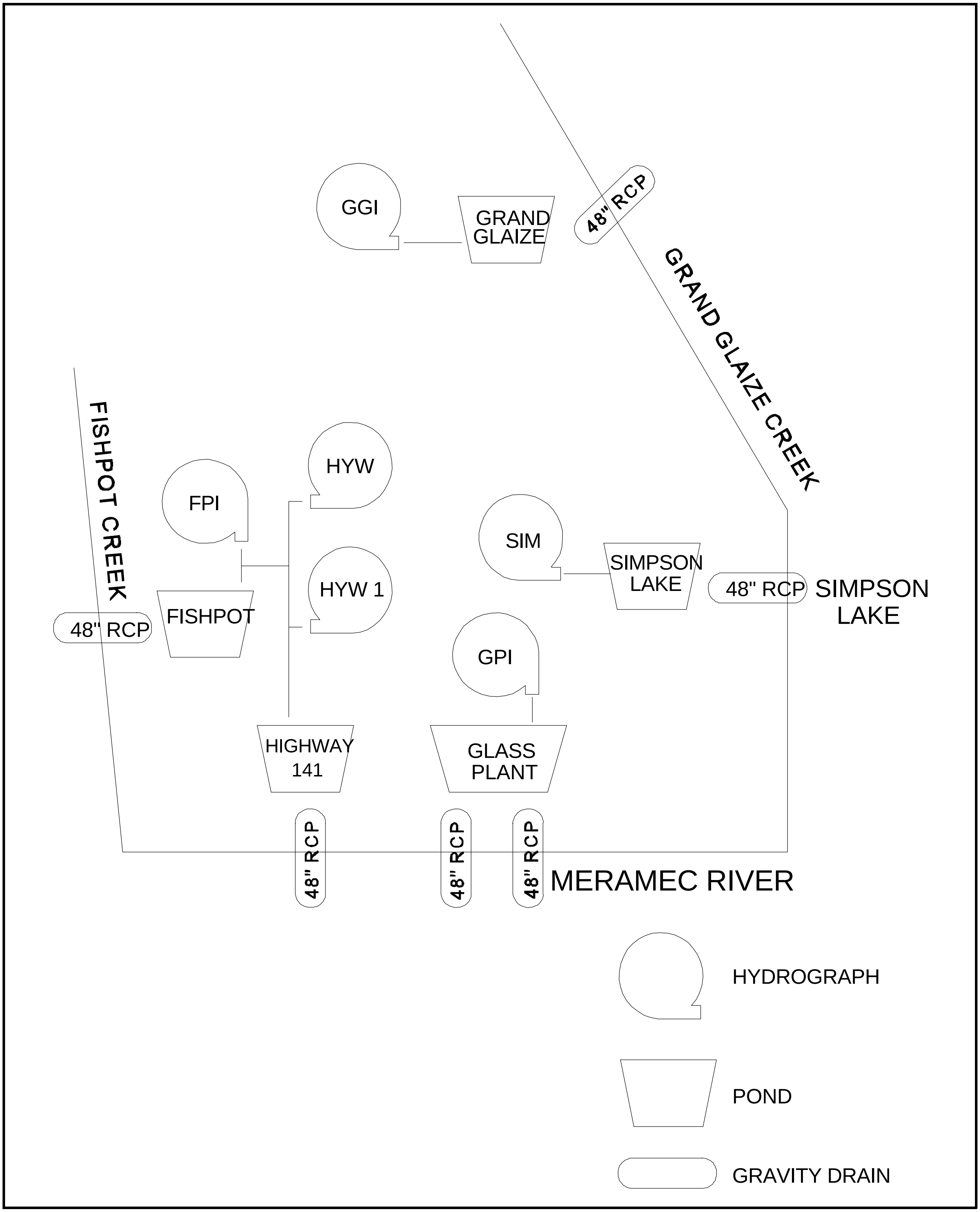

Figure E-1. Schematic of Valley Park interior hydrology project

e. Interior storage areas. Preliminary borrow requirements, along with any natural storage available, were identified at each site. As borrow requirements became more specific throughout the course of the levee investigation, elevation-storage relationships were developed and refined. Elevation-storage relationships are shown in Table E-3.

f. Gravity outlet rating curves. Discharge-stage relationships were developed for 48-, 54-, and 60-in. reinforced concrete pipes (RCP). A minimum diameter of 48 in. was used because each subarea's existing storm outlet system entering the area consisted of 24- to 48-in. pipes. The invert elevations for each outlet were selected based on evaluating the stage-duration data available through HEC-IFH for the period of record and the necessary interior storage. Invert elevations selected represent a 7-percent exceedance duration or less for the Meramec and do not decrease the desired storage volumes. The gravity outlets would be expected to be unblocked at least 93 percent of the time, lessening the need for supplementary pumping. Gravity outlet rating curves are generated automatically by HEC-IFH, with typical output illustrated in Figure E-2.

Table E-3
Interior Storage Areas

Fishpot		I-141		Glass Plant		Simpson Lake		Grand Glaize	
Elev (ft) (NGVD)	Vol (acre-ft)	Elev (ft) (NGVD)	Vol (acre-ft)	Elev (ft) (NGVD)	Vol (acre-ft)	Elev (ft) (NGVD)	Vol (acre-ft)	Elev (ft) (NGVD)	Vol (acre-ft)
405.0	0.0	415.0	0.0	407.0	0.0	408.0	0.0	410.0	0.0
406.0	0.2	416.5	0.2	409.0	5.4	409.0	0.4	412.5	1.0
407.0	0.9	422.0	2.3	413.0	35.8	412.0	6.3	414.0	4.4
408.0	2.0			420.0	119.1	414.0	25.6	419.0	20.2
420.0	26.0					417.0	59.6	420.0	23.5

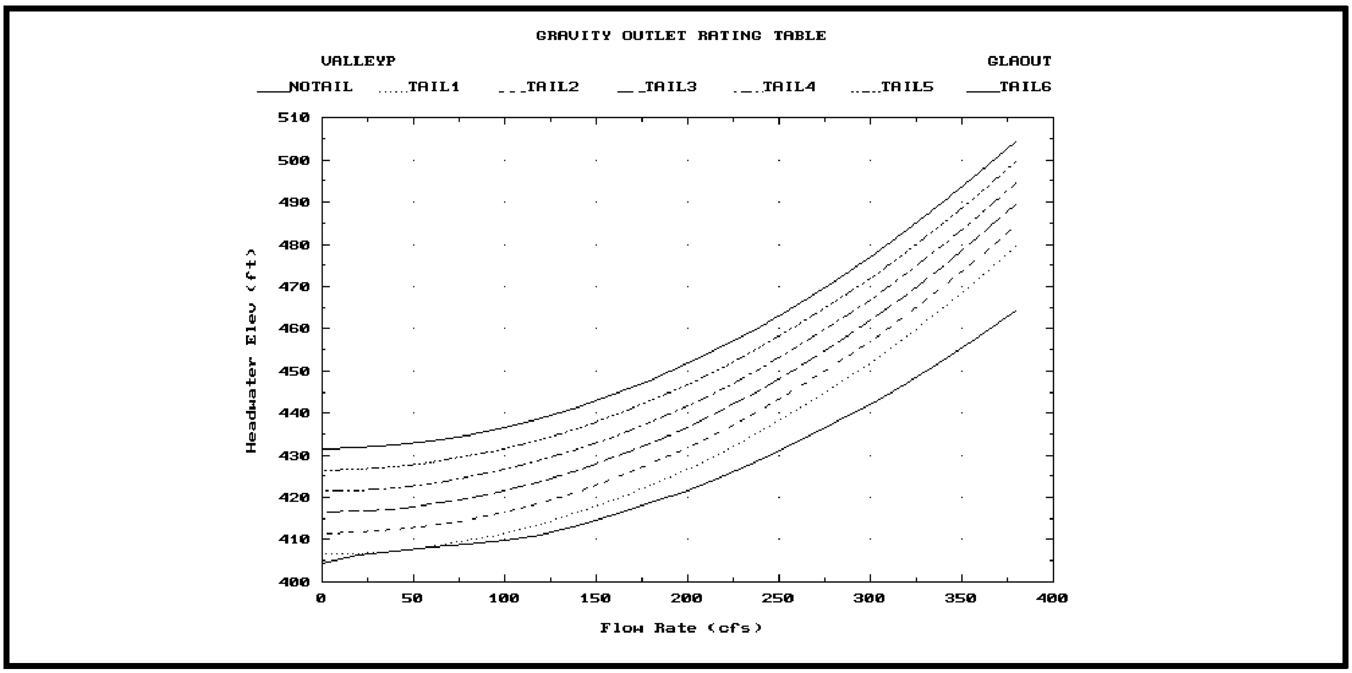

Figure E-2. Gravity outlet rating table for two 48-in. culverts

g. Seepage. Seepage curves for each interior ponding area were supplied by geotechnical personnel to estimate seepage inflow during blocked outlet conditions. These relationships are shown in Table E-4.

h. Auxiliary outflows. One diversion was incorporated to transfer inflow from the upper subarea for the Highway 141 basin to the Fishpot subarea during blocked outlet conditions at the Highway 141 site. Figure E-1 shows the diversion location.

i. Flank levee exterior elevations. Because some gravity outlet structures discharge into Fishpot and Grand Glaize Creeks, exterior river elevations for these structures can change rapidly during local rainfall events independent of the Meramec elevations. Consequently, the blocked outlets at these sites could be caused by either Meramec River backwater, by Fishpot or Grand Glaize Creek flows, or a combination of the two. Water surface profile analyses were performed for a variety of tributary discharges coincident with the full range of Meramec River backwater elevations. Unit hydrographs and runoff coefficients were used to generate hydrographs at each flank levee outlet site. With HEC-IFH, one can enter a family of curves with the tributary discharge and Meramec backwater elevation to determine the corresponding elevation at the tributary gravity outlet site. Figures E-3 and E-4 illustrate this procedure. Consequently, blocked outlets from either the Meramec or from the tributary could be included. Grand Glaize and Fishpot Creek parameters are shown in Table E-5.

E-5. Minimum Facility

A minimum facility was evaluated at each of the five subareas using both the HEA and the CSA techniques.

a. HEA. HEA was performed for both blocked and unblocked outlet conditions, using hypothetical storm rainfall, subarea runoff, available interior storage, and a minimum gravity outlet diameter. Stage-frequency relationships for both blocked and unblocked conditions were determined. Larger gravity outlets were evaluated, but essentially no improvement in interior peak stages was noted, due to the ponding storage available at each site.

Table E-4
Seepage Curves for Ponding Areas

Fishpot		I-141		Glass Plant		Simpson Lake		Grand Glaize	
Head (ft)	Seepage (cfs)	Head (ft)	Seepage (cfs)	Head (ft)	Seepage (cfs)	Head (ft)	Seepage (cfs)	Head (ft)	Seepage (cfs)
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24.1	1.0	24.1	0.8	1.0	0.8	1.0	0.6	24.0	0.8
26.1	1.1	26.1	1.0	2.0	1.5	3.0	1.8	26.7	1.0
29.7	1.2	29.7	1.1	3.0	2.3	4.0	2.4	29.7	1.1
36.2	1.3	36.2	1.2	5.0	3.8	5.0	3.0	36.2	1.2
				10.0	7.5	10.0	6.0		
				15.0	11.3	15.0	9.0		
				20.0	15.0	20.0	12.0		
				25.0	18.8	30.0	18.0		
				30.0	22.5				

Table E-5
Exterior Unit Hydrograph Parameters

Exterior Location	Drainage Area (sq mi)	Runoff Coefficient (percent)	SCS T(Lag) (hr)
Fishpot Creek	10.1	85	.90
Grand Glaize Creek	23.7	85	1.58

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Study ID VALLEYP
Module ID COINFPME

Exterior Stage (EXSTAGE)

Tributary Rating Table

Tributary Flow (cfs)	Tributary Elevations (ft)						
	Main River Elev (1) 392.00	Main River Elev (2) 400.00	Main River Elev (3) 408.00	Main River Elev (4) 416.00	Main River Elev (5) 424.00	Main River Elev (6) 432.00	Main River Elev (7) 436.00
0.0	395.60	400.00	408.00	416.00	424.00	432.00	436.00
500.0	399.83	400.70	408.04	416.01	424.01	432.01	436.01
1000.0	401.80	402.10	408.15	416.02	424.02	432.02	436.02
2000.0	404.60	404.59	408.58	416.10	424.03	432.03	436.03
3000.0	406.59	406.57	409.24	416.22	424.06	432.04	436.04
4000.0	408.30	408.26	410.06	416.39	424.10	432.05	436.05
5000.0	409.80	409.77	410.94	416.60	424.16	432.07	436.06
6000.0	411.10	411.11	411.85	416.86	424.23	432.31	436.31
7000.0	412.30	412.28	412.72	417.15	424.32	432.43	436.42
8000.0	413.30	413.29	413.59	417.48	424.41	432.56	436.54

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Figure E-3. Tributary rating table

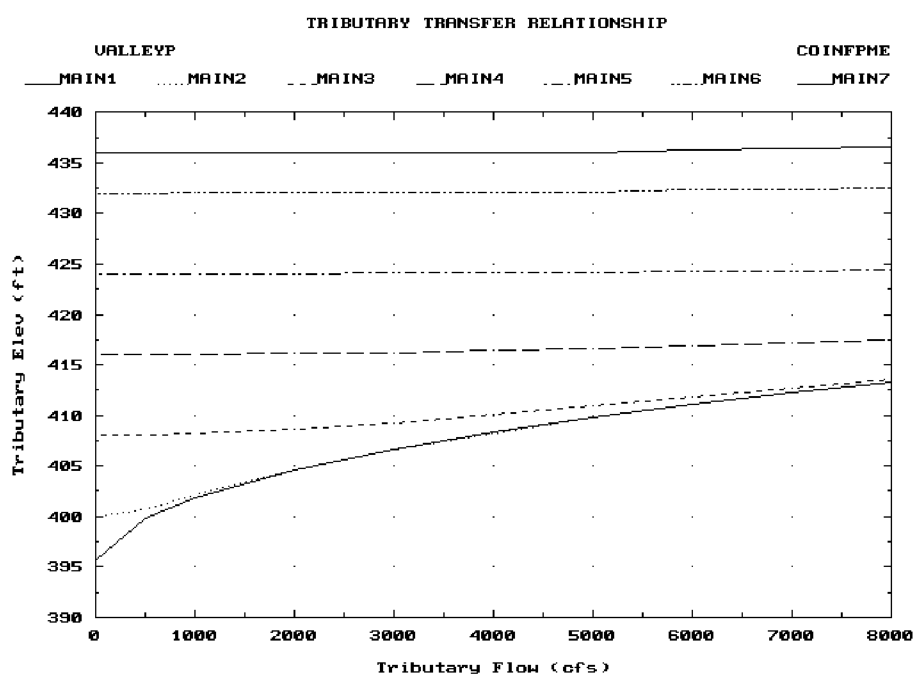

Figure E-4. Plot of tributary rating table *b. CSA.*

(1) Data were used to prepare a CSA for each of the five subareas. Trial runs of HEC-IFH initially were made on an expanded memory 386/25 PC using a 10-min time increment. These early trials resulted in extremely lengthy run times. Runs of 8 to 10 hr were typical, with the run aborting before completion of the CSA due to inadequate computer storage. The acquisition of a 486/33 PC during this phase lessened the problem; however, it was decided to modify the time-step to 1 hr to improve the computation performance. The interior inflow hydrographs would not be adequately defined; however, the inflow volume would be acceptable for routing through the storage areas and out the gravity outlet(s). Using a 1-hr time step for the 40 years of record resulted in about 3 hr of computation time for a 486/33 PC. The CSA gave a continuous stage-hydrograph of ponding elevations and the drain outflow for each site. Annual peak values could then be extracted for graphical display. The stage-frequency relationships resulting from the CSA method were very comparable with the HEA results, falling between the HEA stage-frequency relationships for blocked and unblocked conditions.

(2) The results of the CSA were used to determine the minimum facility, which is shown in Table E-6. Table E-7 compares the results of the HEA and CSA for the 100-year average return period event at one site. Each gravity outlet was analyzed similarly. The hydraulic design details for the gravity outlets planned for the minimum facility are shown in Table E-8.

Table E-6
CSA Interior Analysis Summary (Minimum Facility)

Area Location	Gravity Outlet Size (in.)	Ponding Size (acre-ft) (1% Chance)	Maximum Pond Elev (NGVD) (1% Chance)
Fishpot	1-48	24.8	419.4
Highway 141	1-54	1.9	421.2
Glass Plant	2-48	100.5	418.2
Simpson Lake	1-48	42.7	415.5
Grand Glaize	1-48	20.6	419.2

Table E-7
Comparison of HEA and CSA for the 1-Percent Event

Area Location	HEA Results Closed Outlet (acre-ft)	CSA Results (acre-ft)
Fishpot	32.0	24.8
Highway 141	8.4	1.9
Glass Plant	148.2	100.5
Simpson Lake	44.0	42.7
Grand Glaize	36.1	20.6

Table E-8
Gravity Outlets

	RCP	Invert		
Location	Size (in.)	Inlet (NGVD)	Outlet (NGVD)	Length (ft)
Fishpot Creek	48	405.0	403.00	198
Highway 141	54	414.4	412.74	163
Glass Plant				
3rd Street	48	405.0	400.89	574
5th Street	48	405.0	397.79	1128
Simpson Lake	48	408.0	405.57	341
Grand Glaize	48	410.5	408.50	152

E-6. Plan Summaries

Individual CSA runs are obviously quite lengthy. One CSA run for a Valley Park subarea, using 1-hr intervals with 40 years of record, yields about 3,900,000 bytes of output. The total output for the various Valley Park plans now retained in the computer requires about 85 MB of storage, a veritable "mountain" of paper. Thus an extremely valuable feature to analyze output is the plan summary tables available within HEC-IFH, which allow the easy comparison of several different plans or scenarios. Examples of some plan summary displays are shown in Figures E-5, E-6, and E-7. These results compare interior elevations, area flooded, stage-frequencies, etc. for the Glass Plant subarea for gravity outflow conditions of two 48-in. outlets (GLASMOD1), two 54-in. outlets (GLASMOD2), and two 60-in. outlets (GLASMOD3). As is readily apparent, there is no significant improvement in the results for larger gravity outlets than the minimum facility (two 48-in. outlets).

E-7. Graphical Displays

Another valuable feature of the HEC-IFH Package is the ease of preparing report quality graphical displays of key information. Figures E-8 through E-13 give examples of graphical information used for the Valley Park FDM. These figures show the monthly maximum, average and minimum ponding stages, and exterior river stages for the period of record. They also show the stage-duration curves for both annual maximum outflow and acres flooded in the ponding area, and the interior stage-frequency relationship from the CSA.

E-8. Summary

HEC-IFH proved to be a useful tool in analyzing the Valley Park interior area. The St. Louis District will continue to use HEC-IFH for interior studies.

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Study ID VALLEYP

Comparison of Plans

A. Analysis Summaries - Maximum Values

Plan ID	Exterior Elev. (ft)	Interior Elev. (ft)	Interior Area Flooded (ac)	Head Differential Maximum (ft)	Head Differential Minimum (ft)	Pump Data Head (ft)	Pump Data Outflow (cfs)
GLASMOD2	430.21	417.76	15.3	14.95	-18.89	0.00	0.0
GLASMOD3	430.21	417.76	15.3	16.54	-18.89	0.00	0.0
GLASMOD4	430.21	417.76	15.3	14.33	-18.89	0.00	0.0

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Figure E-5. Maximum values for study plans

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Study ID VALLEYP

Comparison of Plans

F. Interior Analysis - Maximum Interior Elevations

Plan ID	Area Prim. Grav. (sqft)	Total Pump Cap. (cfs)	Peak Elevation (ft) vs. Percent Chance Exceedence Frequency Event						
			50%	20%	10%	4%	2%	1%	0.2%
GLASMOD2	25.1	0.0	410.87	413.79	414.94	417.38	417.71	417.95	418.53
GLASMOD3	31.8	0.0	410.91	413.79	414.94	417.38	417.71	417.95	418.53
GLASMOD4	39.3	0.0	410.87	413.79	414.94	417.38	417.71	417.95	418.53

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Figure E-6. Maximum interior elevations for study plans

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Study ID VALLEYP

Comparison of Plans

H. Interior Analysis - Maximum Interior Area Flooded

Plan ID	Area Prim. Grav. (sqft)	Total Pump Cap. (cfs)	Maximum Interior Area Flooded (ac) vs. Percent Chance Exceedence Frequency Event						
			50%	20%	10%	4%	2%	1%	0.2%
GLASMOD2	25.1	0.0	0.0	0.0	0.0	0.0	0.1	3.1	14.8
GLASMOD3	31.8	0.0	0.0	0.0	0.0	0.0	0.1	2.9	14.7
GLASMOD4	39.3	0.0	0.0	0.0	0.0	0.0	0.1	2.8	14.7

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Figure E-7. Maximum interior area flooded for study plans

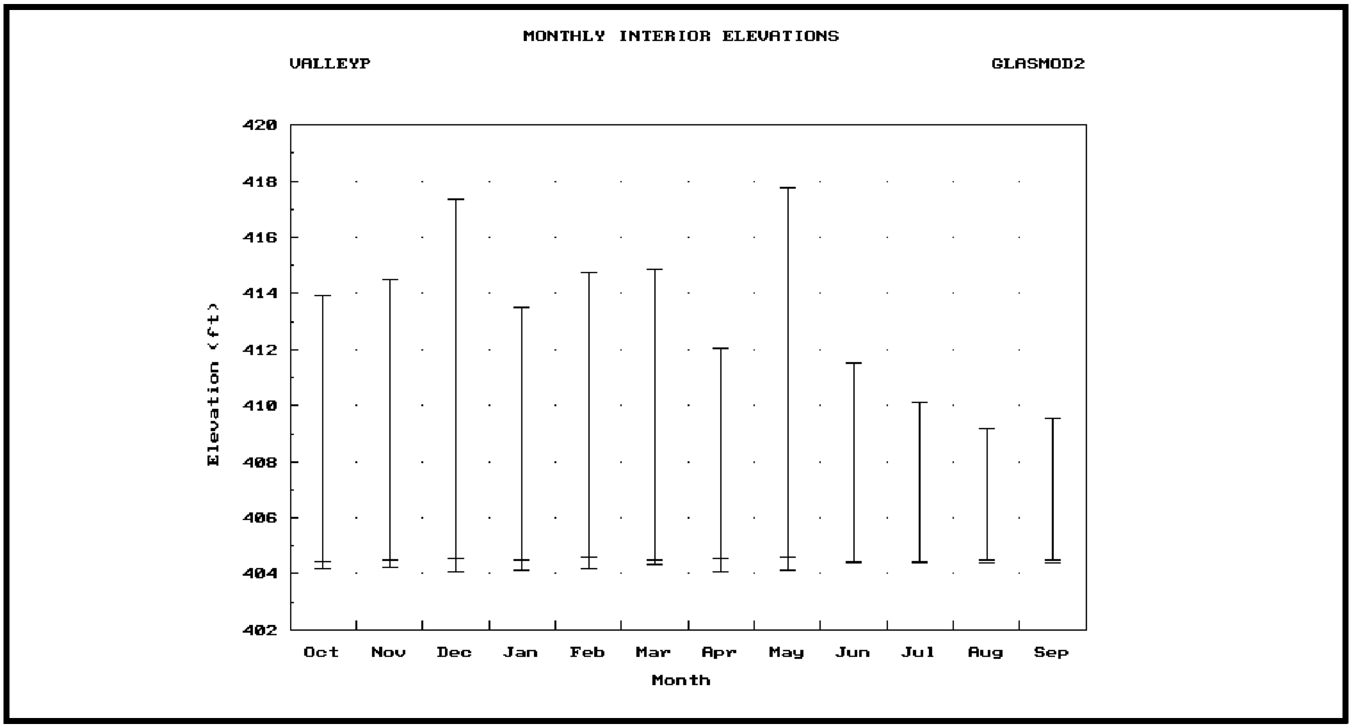

Figure E-8. Monthly interior elevations for glass plant basin

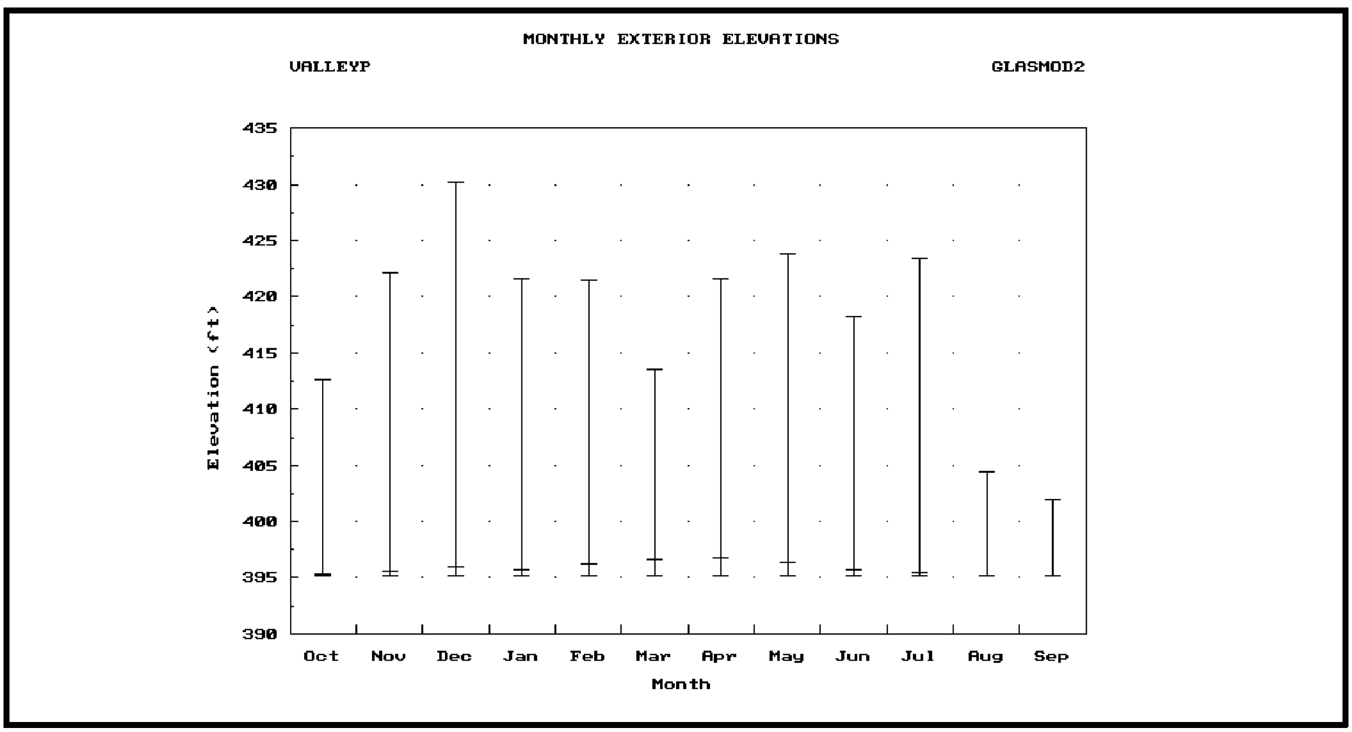

Figure E-9. Monthly exterior elevations for glass plant basin

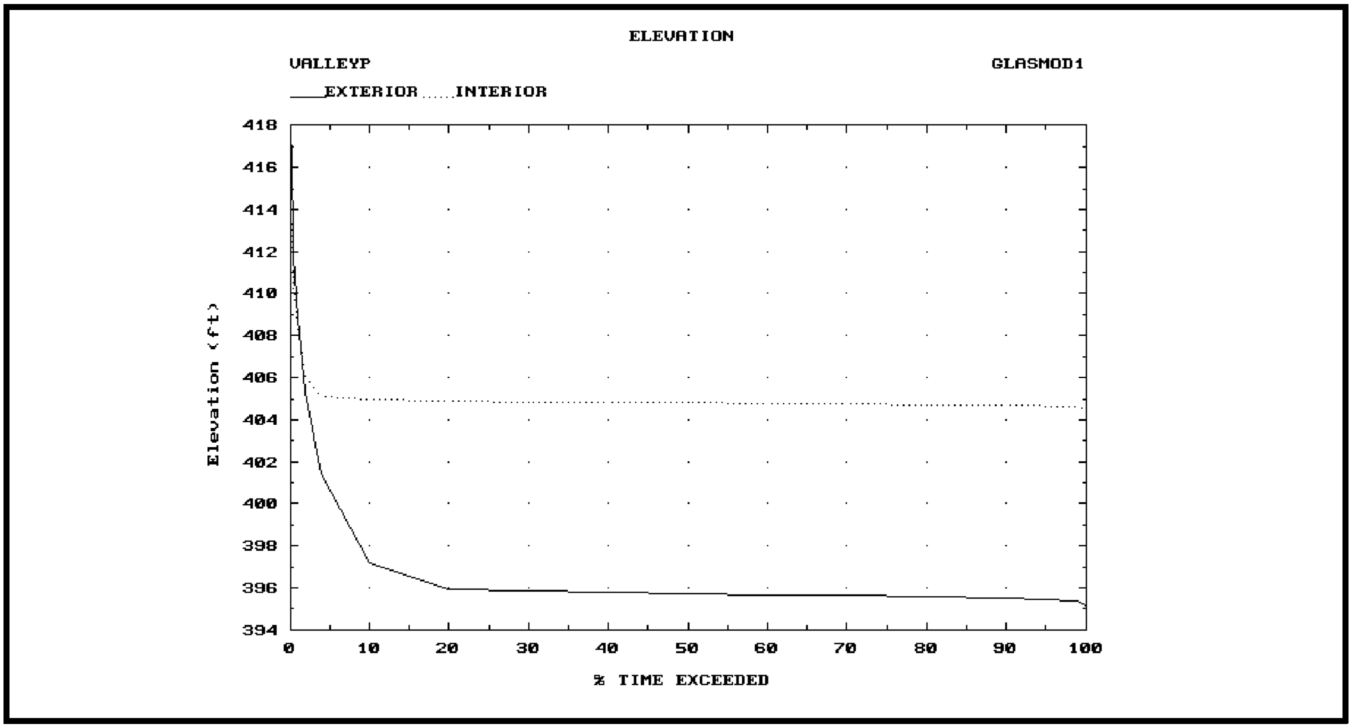

Figure E-10. Interior and exterior stage duration relationships for glass plant basin

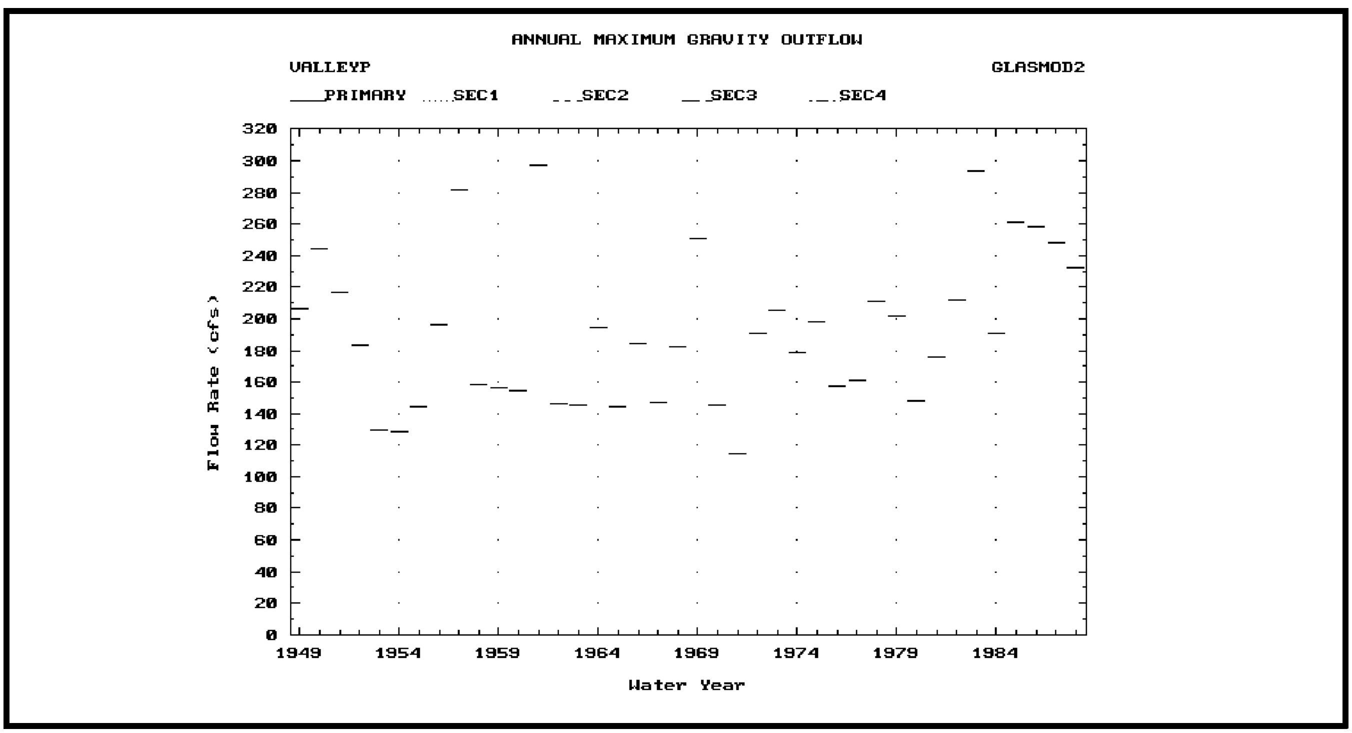

Figure E-11. Maximum annual gravity outflow

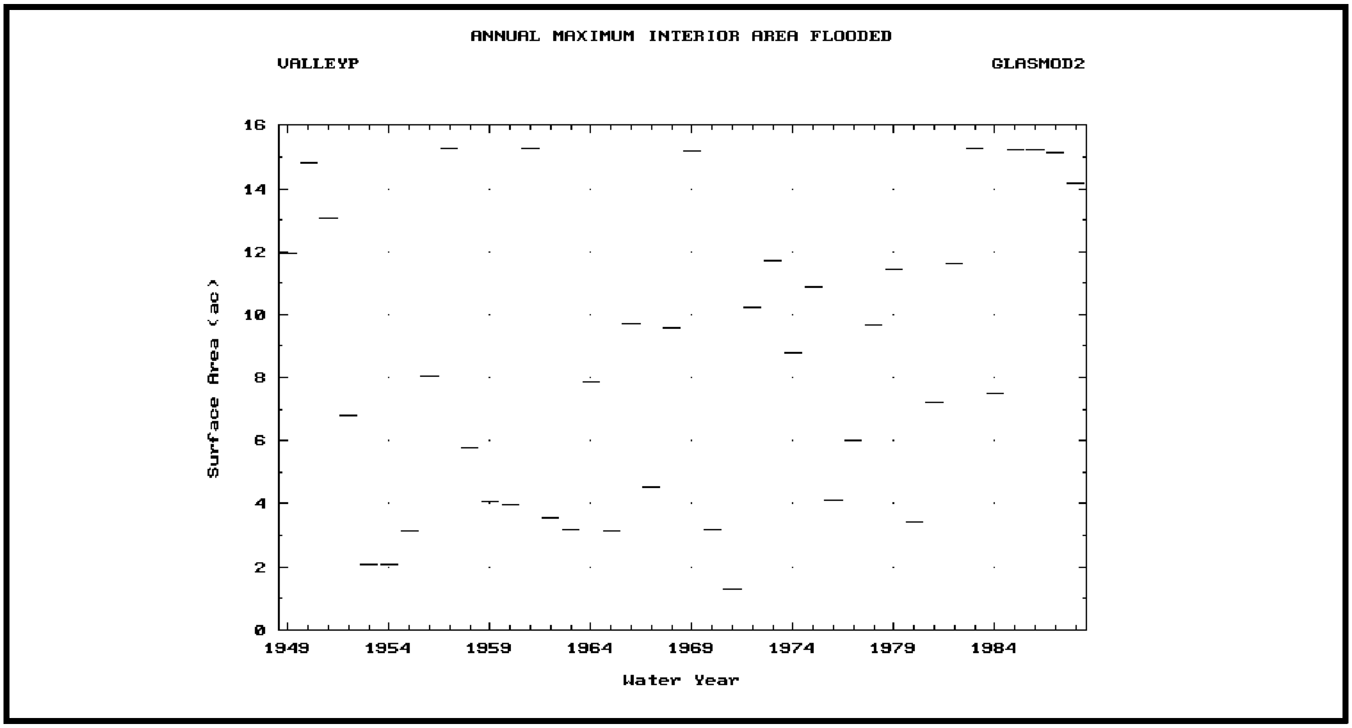

Figure E-12. Maximum annual interior area flooded

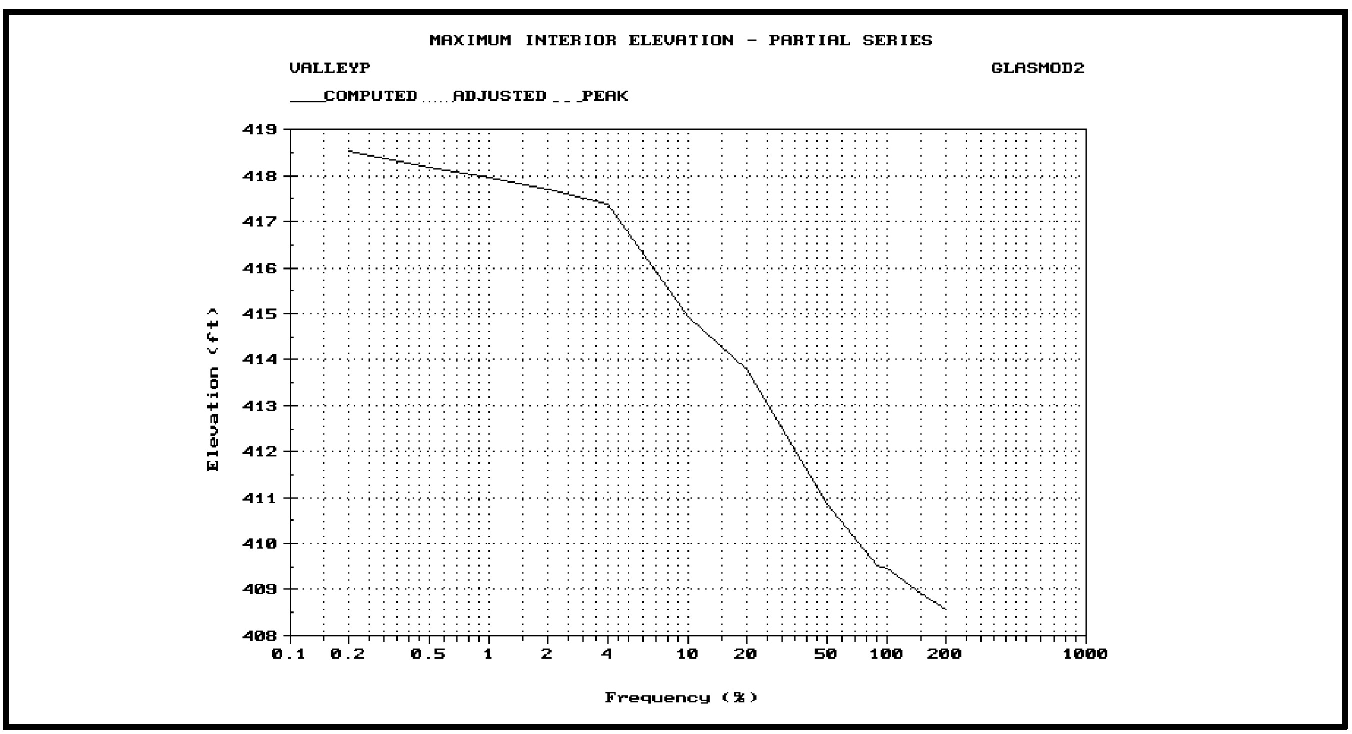

Figure E-13. Interior elevation - frequency for glass plant basin